Perceptual and Motor Skills, 1984, 58, 151-158.

THE PEDOMETER: A REASSESSMENT OF ITS USEFULNESS IN THE MEASUREMENT OF ACTIVITY LEVEL

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Summary.—The feasibility of using the pedometer to measure activity level was investigated. 35 male and 49 female subjects wore a pedometer and kept an activity diary for five consecutive days. The correlation between the two measures and the day-to-day reliability were examined. The pedometer showed high reliability and was strongly correlated ($r = .72$) with the diary. It was suggested that the pedometer particularly when combined with a descriptive tool, such as a diary, can be useful in research on the relationship of activity level to overweight and other health-related behaviors.

The relationship between level of physical activity and health has long been of interest to behavioral researchers. For example, low levels of energy expenditure were first implicated in the etiology of obesity over forty years ago (Bruch, 1940). Similarly, low levels of physical activity were suggested as playing a role in coronary heart disease three decades ago (Taylor, *et al.*, 1949). More recently, physical activity has been linked with depression (Griest, *et al.*, 1979), anxiety (Pitts, 1969), and over-all mental health (Jette, 1975). At the present time it is unclear how critical activity actually is in the development or maintenance of any health-related problem. In research on obesity, for example, there have been numerous studies supporting the importance of a low level of activity as a causal factor (Johnson, *et al.*, 1956; Bullen, *et al.*, 1964; Gwinup, 1975), but there have been many others who reported a nonsignificant or modest relationship between activity level and obesity (Strefanik, *et al.*, 1959; Lincoln, 1972; Bradfield, *et al.*, 1971).

One factor that may be contributing to the confusion is the number of ways in which activity has been measured. Methods that have been used include: motion picture sampling (Bullen, *et al.*, 1964); pedometers (Dorris & Stunkard, 1957); actometers (Stevens, *et al.*, 1978); electronic body movement monitors (LaPorte, *et al.*, 1979); electronic heart rate recorders (Saris, *et al.*, 1977), experimenters' observation (Brownwell, *et al.*, 1980); activity diaries (Bradfield, *et al.*, 1971); subject's recall of activity (Johnson, *et al.*, 1956); questionnaires administered by trained interviewers (Taylor, *et al.*, 1978); a self-administered questionnaire (Baecke, *et al.*, 1982), and structured interviews (Kannel & Sorlie, 1979). The existence of so many methods of measuring activity level attests to a lack of consensus about an optimal method of measurement.

There also appears to be some disagreement about what is being measured.

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To date, even the most elaborate and sophisticated measurement tools only provide an index of how physically active someone has been during a given period of time. In addition, the more elaborate devices are often too complex and expensive to be used in studies involving more than a small number of subjects. Particularly in behavioral studies, where different groups of individuals are being compared, there is a need for a valid and reliable method of measuring activity which is also rapid and inexpensive.

One of the earlier methods of quantitatively measuring activity level is the pedometer. Although it has been criticized for being imprecise (LaPorte, *et al.*, 1979) and limited in what it measures (Baecke, *et al.*, 1982), it has the advantages of being inexpensive and easy to use. The present study, which was part of a larger study on body weight regulation (Edelman, 1983), had three purposes. The first was to examine the feasibility of the pedometer as a method of measuring an individual's level of physical activity as well as to examine the relationship of the pedometer to other measures of activity, namely, a questionnaire and activity diary. As no universally accepted standard of activity level exists, correlating three different techniques serves as a first step toward establishing validity of the pedometer. The second purpose was to establish the reliability of the pedometer in terms of daily variations of physical activity. Finally, the relationships of physical activity to age, sex, and body weight were examined.

METHOD

Subjects

Eighty-four subjects (49 female and 35 male) agreed to participate in the experiment on activity level and behavior. They included undergraduate and graduate students ($n = 44$), college staff ($n = 8$), and employees of the US Army Natick Research and Development Laboratories ($n = 32$). Subjects ranged in age from 17 to 51 yr.; their mean age was 26.5 yr. Mean percent overweight was 11% with a range from −16% below to 68% above Metropolitan Life Insurance (1959) height/weight standards. Sixteen of the subjects did not complete the diary in sufficient detail for scoring. Comparisons of pedometer, diary and questionnaire scores were performed on the remaining 68 subjects.

Procedures

The study was conducted in two parts: a five-day period (including a weekend) during which activity level was measured and a follow-up laboratory session. The results of the laboratory session are reported elsewhere (Edelman, 1983) and will not be discussed in detail here. The experimenter gave subjects a digital pedometer (Model No. 970 Manpo-Meter Co.) and a diary. The pedometer recorded up and down movements of the lower parts of the

body. A total in tenths of miles appeared on a counter. Subjects were asked to record this total every 3 hr.

Subjects were told:

> We are interested in finding out more about individual differences in routine daily activity habits. While we are interested in any sports you might participate in, we are just as interested in finding out about behaviors like walking, eating, dancing, resting, in short, all of the activities which make up your daily routine.
>
> Currently, no single measure exists for studying activity habits. Therefore we are asking you to do two things. (1) Wear this pedometer. Clip it onto your belt or waistband when you get dressed in the morning and go about your daily routine. Every three hours enter the total on the counter into the appropriate place at the back of your diary. For example, if you put the pedometer on at 7:30 am, your first entry should be at 10:30 am, your second at 1:30 pm, your third at 4:30 pm, and your final entry at 7:30 pm. After the last entry, reset the pedometer to 0. (2) We also want you to fill out an activity diary. As you see there is a place for the activity, the time you begin and the time you finish. Please be as descriptive as possible.

Subjects were asked to keep these records for a period of five consecutive days including a weekend.

At the end of the five-day period, subjects were asked to complete a short questionnaire (see Appendix A) of items assessing behaviors and attitudes about activity.

Scoring

Pedometer scores were based on daily total recorded units of movement. When worn at the waist, the pedometer records up and down movements of the lower body. It can be calibrated for stride to measure distance walked or run. For the purposes of the study, total movement was of interest regardless of the actual distance moved. There was no attempt to measure how far an individual moved during a given period. Each subject had five pedometer scores based on the total for each day. Each day of the activity diary was also coded separately. The daily diary scoring was based on the type, amount, and duration of activities and was based on standards developed by the Presidents' Council on Physical Fitness (1967). Each questionnaire item was scored separately. An answer of "not at all" was scored 0, "slightly" was scored 1, "moderately" was scored 2, and "greatly" was scored 3.

RESULTS

Reliability

The Pearson correlations showed the average value of the five pedometer readings to be .58, with a range of .47 to .69. The Cronbach's α (Cronbach, 1951) of the scale constructed from the sum of the five measures was .87. All five days readings were equally important in determining the over-all reliability

as can be seen when each item is individually omitted in computing alpha. Dropping items one to five yields αs of .83, .84, .86, .84, and .84.

The average intercorrelation of the five diary measures was .49 (range = .35 to .62); that was lower than the average intercorrelation of the pedometer readings. The scale constructed from the sum of the items had a reliability of .82. Again, the items did not substantially differ in their contribution to alpha. Omitting each item one at a time resulted in alphas of .77, .80, .82, .77, and .79.

Both scales are reliable when based on five measures each. If measurements over a five-day period were not feasible, however, estimates of the reliability of a truncated scale could be made by means of the Spearman-Brown formula (Ghiselli, 1964). For the pedometer scale: two days = .66; three days = .74; four days = .79. The reliability of a scale based on one day is simply the average intercorrelation among the five pedometer scores, i.e., .58.

Validity

The pedometer and diary scales intercorrelated .61 ($n = 68$, $p < .001$). However, because complete reliability for each scale was lacking, the estimate of the relationship between activity as measured by pedometer and self-report erred on the conservative side. To adjust for this error of measurement, a correction for attenuation was made (Ghiselli, 1964). The attenuation corrected was .72 ($.61/\sqrt{.87 \times .82}$) and estimates that 52% of the variance of the two indices is shared when both are measured with full reliability. The remaining 48% of unshared variance will reflect unique σ^2, method variance, and variance common to other variables.

Questionnaire Items

The intercorrelations of each scale with percent overweight and the activity questions are presented in Table 1. It is apparent that the diary scale was

TABLE 1

CORRELATIONS AMONG MEASURES OF ACTIVITY

Question	Pedometer	Diary	% Overweight
% Overweight	−.26*	−.39†	1.00
1	.28*	.48†	−.20
2	.25*	.41†	−.37†
3	.31†	.37†	−.10
4	.28†	.50†	−.15
5	.26*	.51†	−.21
6	.38†	.52†	−.25*
7	.29†	.32†	−.44†
8	.25*	.47†	−.20
9	.17	.08	−.43†

*$p < .05$. †$p < .01$.

more strongly correlated with the above items than was the pedometer scale. This could be construed as indicating that the diary measure was a more valid measure of activity level than the pedometer scale particularly since it was more highly correlated with percent overweight. However, it should be noted that all of these items (including the data upon which overweight was based) were self-report items, just as the diary measure was. The increased correlations may therefore be a function of shared method variance. For example, subjects may systematically present a favorable image of themselves in terms of being both trim and fit. The pedometer scale, on the other hand, is largely free from this possible response bias. For the data available, both measures had high reliability and were valid indicator's of activity level. It is not possible to determine, at this time, which is the better indicator.

Neither age or gender was significantly correlated with either pedometer or diary scores. In addition, while there was a significant negative correlation between percent overweight and activity level, there was no difference in this relationship on the basis of sex.

Only four of the questionnaire items (Questions 2, 6, 7, 9) were significantly correlated with percent overweight, although all correlations were in the negative direction. People whose answers indicated they were physically active were less likely to be overweight than people whose answers indicated they were inactive. The only questionnaire item not significantly correlated with activity level, Question 9, was moderately negatively correlated ($-.43$, $p < .01$) with being overweight. People who described themselves as staying physically fit without engaging in much formal exercise were unlikely to be overweight but did not have high activity levels as measured by either the pedometer or the diary.

Discussion

The present study demonstrates the usefulness of two techniques for measuring daily activity level, namely the pedometer and the activity diary. The strength of the correlation between the two measures indicate that, in general, the level of physical activity that people report corresponds with their actual behavior. The correlation was substantial considering the two very different types of measures used.

Several factors help explain the lack of complete agreement between the two measures. The pedometer was worn at the waist and did not measure upper body movement. In a study using an electronic activity monitor a stronger correlation ($r = .72$) was found between ankle and trunk movements (LaPorte, 1979). It is unclear what the correspondence would be between ankle and trunk movement using a mechanical pedometer. Presumably this difference contributes to the lack of total agreement between the two measures. In addition, the pedometer could not be used at all to measure certain types of activities,

for example, aerobics and all watersports. There were also substantial differences in how thorough participants were in completing the activity diary. Some diaries could be coded more completely than others. This type of problem has been observed in a study that measured the activity habits of British civil servants by means of a diary-type questionnaire. These investigators suggest that the questionnaire used in that study might not be useful with other groups who lack the ability or motivation to keep careful records (Taylor, *et al.*, 1978). The solution of Taylor and his colleagues was to develop a questionnaire to be administered by trained interviewers, a method which was shown to be valid but labor intensive. In view of problems with the diary, a feasible and non-labor intensive method may be a structured activity diary where types and durations of activities could be easily rated every few hours.

The results of several studies suggest that daily activity level has several components. For example, on the basis of a self-administered questionnaire, Baecke and his colleagues (1982) identified three components to activity: physical activity at work, sports during leisure time, and physical activity during leisure excluding sports. Their finding supported earlier suggestions that occupational and leisure activity levels may be poorly related (Morris, *et al.*, 1973; Hickey, *et al.*, 1975).

A single method may be insufficient to measure gross activity level. A study of children's activity levels compared scores from actometers, modified wristwatches which measure voluntary muscle movement, with observers' ratings. Correlations ranged between —.21 and .77 depending upon the observer and the situation in which the observation was made. The authors concluded that both types of measures, qualitative and quantitative, may be necessary to get an accurate picture of activity level (Stevens, *et al.*, 1978). The present results also suggest that a more useful indication of activity level can be achieved through the use of both quantitative and qualitative measures than by using either type of measure alone. The present results also indicate that both the pedometer and the diary are reliable indicators of daily activity level. However, sampling should be done for several days to ensure high reliability. Given the complex nature of daily activity, short-term measurement is insufficient to obtain reliable data. In making the decision of how many days to use one should consider the desired reliability of the scale and the expense or feasibility of collecting the data.

The negative relationship between percent overweight and activity level was significant. This supports previous findings (Johnson, *et al.*, 1964; Bullen, *et al.*, 1963) on the relationship of activity level and percent overweight. Both the pedometer and the diary were better predictors of overweight than the questionnaire items. Opinions about activity, as measured by the present questionnaire, are unrelated to being overweight.

There is some evidence that differences in the efficiency of energy utilization may play an unspecified, but important role in body-weight regulation (Garrow, 1974; Miller & Parsonage, 1975). The high correspondence between answers to Question 9, activity level and percent overweight offers tentative support to the notion that some metabolic factor makes obesity more or less likely. Apparently, there are people who feel they stay thin or at least physically fit without engaging in much exercise. Independent measures of activity level (pedometer) agree with their self evaluations. It should be noted, however, that in the present study there is no measure of successful dietary restraint. It is likely that some individuals stay thin through purposefully reducing their intake and for them activity level may be irrelevant. This issue needs to be investigated further.

In conclusion, the mechanical pedometer does provide a valid and reliable measure of activity level. The pedometer, particularly when combined with a qualitative tool, such as a diary, can be useful in research on the relationships of physical activity to obesity and other health-related behaviors.

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Accepted December 13, 1983.

APPENDIX A

QUESTIONNAIRE ITEM

1. How important is exercising and actively participating in sports compared with your other activities?
2. Which best describes your lifestyle with respect to physical activity?
3. How much does your level of physical fitness affect the way you feel about yourself?
4. How intensely do you usually exercise?
5. When you are upset or anxious, how likely are you to exercise?
6. When you have nothing else to do how likely are you to exercise?
7. I must be fairly active because I eat a lot and still stay thin.
8. When you are bored how likely are you to exercise?
9. I find I stay physically fit without engaging in much exercise.